NATIONAL ENVIRONMENTAL MONITORING COMMISSIONED BY THE SWEDISH EPA

SWEDISH ENVIRONMENTAL PROTECTION AGENCY

Report

Screening of concrete additives

Naturvårdsverket

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About the report

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Summary

To reduce the total use of materials in society, it is important that more materials are recycled or re-used. According to the EU, at least 70% of all non-hazardous building and demolition waste should be recycled or re-used by 2020. Since concrete makes up a large proportion of all such waste, reaching this goal will require that concrete is re-used. This means that concrete that historically has been disposed on landfills will in the future be increasingly used as fill material in different types of construction applications.

Various additives are used to improve the properties of concrete. For example, air-entraining agents are used to prevent cracks when the concrete freezes, and accelerators speed up hydration (hardening) of the concrete. Some of these additives have environmentally hazardous properties. When more concrete is re-used instead of ending up on landfills, there is an increased risk that these chemicals are spread in an uncontrolled way. These chemicals may also pose an environmental risk at landfills, although leachate water from landfills is better controlled and the risk is therefore smaller.

During 2012 and 2013, EnviroPlanning performed a screening study of concrete additives at one landfill and two sites where concrete has been used in the road construction. The study was ordered by the Swedish Environmental Protection Agency (Naturvårdsverket). All analyses were performed on water samples.

The specific goals of the project were:

- to determine if these additives are likely to reach the aquatic environment by leaching from landfills and fill materials
- to compare environmental concentrations to hazardous concentrations and determine the environmental risk
- to provide examples of suitable action to reduce the environmental risk

The study has shown that the ecological risk associated with additives in concrete is low. No precautionary measures are suggested to reduce emissions from recycled concrete or concrete landfills.

Sammanfattning

För att minska materialåtgången i samhället är det viktigt att så mycket som möjligt återanvänds. Enligt EU:s ramdirektiv för avfall skall minst 70% av allt icke-farligt byggnads- och rivningsavfall återanvändas år 2020. Eftersom betong utgör en stor del av allt byggnads- och rivningsavfall krävs det att betong återanvänds för att det skall vara möjligt att nå detta mål. Detta betyder att betong som idag läggs på deponier i större utsträckning kan komma att användas som ballast- och utfyllnadsmaterial vid anläggningarbeten.

För att förbättra betongens egenskaper används ofta olika tillsatser. Exempelvis tillsätts luftporbildare för att förhindra att betongen spricker vid minusgrader och härdningsacceleratorer för att påskynda härdningsförloppet. En del av dessa tillsatser har miljöfarliga egenskaper. Då mer betong återanvänds istället för att hamna på deponier så ökar risken att dessa ämnen sprids på ett okontrollerat sätt i samhället. Även deponier för betongavfall kan utgöra en miljörisk, även om dessa är bättre kontrollerade och risken därmed är mindre.

På uppdrag av Naturvårdsverket har EnviroPlanning under 2012 och 2013 genomfört en screening av betongtillsatser vid en deponi samt vid två platser där krossad betong har använts vid vägarbeten. Samtliga prover har tagits i vatten.

Projektets målsättning har varit:

- att bedöma om det är troligt att dessa ämnen kan nå vattenmiljön genom läckage från deponier eller utfyllnadsmaterial
- att jämföra koncentrationer i miljön med toxiska koncentrationer och bedöma miljörisken
- att ge förslag på lämpliga åtgärder för att minska ett eventuellt läckage

Projektet har visat att de ekologiska riskerna med läckage av tillsatser från återvunnen betong som används i anläggningarbeten är låg. Inga försiktighetsåtgärder föreslås därför för att minska läckaget från återanvänd betong eller betongdeponier.

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1 Introduction

1.1 Background

Use of various construction materials in society entails substantial environmental costs during extraction, manufacture, transport and disposal. To reduce material use, and thereby environmental costs, certain types of material can be recycled. According to the EU's waste framework directive, at least 70% of all non-hazardous construction and demolition waste should be recycled by 2020. One type of material that is affected by this directive is concrete, which makes up a large proportion of all construction and demolition waste. This means that a larger proportion of the concrete that is today disposed of at landfills must be recycled, e.g. as fill material in earthwork.

Additives are often used to improve the properties of concrete. For example, air entraining agents are used to prevent cracks when the concrete freezes, and accelerators speed up hydration (hardening) of the concrete. Some of these additives are environmentally hazardous, e.g. resin acids Peng och Roberts 2000) and thiocyanate (Lanno and Dixon 1994). These substances have also been shown to leach from concrete, and risk entering the wider environment. (Togerö 2006). If more concrete is recycled instead of being disposed on landfill, there is an increased risk of these substances spreading uncontrollably. Landfill sites for concrete could also pose an environmental hazard, although these are more rigorously controlled, so the risk is lower.

EnviroPlanning AB was assigned in 2012 and 2013 by the Swedish Environmental Protection Agency (Naturvårdsverket) to conduct screening of concrete additives at a site where demolition concrete has been recycled for use in road construction, and at two landfill sites where large amounts of concrete have been disposed. The screening has been extended to a site in Dalarna, as assigned by Dalarna County Administrative Board, and at Skanska's concrete manufacturing site in Luleå, as assigned by Norrbotten County Administrative Board.

1.2 Purpose

The purpose of the screening study was to investigate the likelihood of a number of substances used as concrete additives leaching out into the aquatic environment. Samples were analysed from a site where concrete waste has been used during road construction, and at two landfill sites where concrete is disposed. The concentrations measured were compared with those at which a toxic effect occurs to evaluate the environmental risk.

2 Procedure, screening of concrete additives

During 2012 and 2013, as assigned by the Swedish Environmental Protection Agency (Naturvårdsverket), surface water analyses were carried out at a site where concrete waste had been used as fill material during road construction, and at two landfill sites where concrete is disposed. The screening was extended to a site in Dalarna, as assigned by Dalarna County Administrative Board, and at Skanska's concrete manufacturing site in Luleå, as assigned by Norrbotten County Administrative Board. Ten concrete additives were analysed in total (Table 1).

Table 1. *Analysed substances and their abbreviation, CAS number and the detection limit.*

Chemical	Abbreviation	CAS number	Detection limit (µg/l)
4-Nonylphenol (branched)	4NP	84852-15-3	0,1
4-Nonylphenol (branched) -1-ethoxylate	4NPEO1	104-35-8	0,1
4-Nonylphenol (branched) -2-ethoxylate	4NPEO2	20427-84-3	0,1
4-tert-Octylphenol	4tOP	140-66-9	0,01
4-tert-Octylphenol-1-ethoxylate	4tOPEO1	2315-67-5	0,01
4-tert-Octylphenol-2-ethoxylate	4tOPEO2	2315-61-9	0,01
Total concentration of thiocyanates expressed as sodiumthiocyanate	Thiocyanate	540-72-7	5
Pimaric acid	Pimaric acid	127-27-5	1
Abietic acid	Abietic acid	514-10-3	1
Dehydroabietic acid	Dehydroabietic acid	1231-7-0	1

Table 2 shows a list of all the sampling points with coordinates. The sites and sampling procedure are described in more detail below.

Table 2. *Sampling points*

Site	Point	Position (SWEREF)
1. Road, Tanumshede	1 (reference)	6519468 284797
	2 (road)	6517500 285801
	3 (downstream wetland)	6517400 285528

Site	Point	Position (SWEREF)
2. Fläskebo landfill, Landvetter	4 (leachate)	6397340 330092
	5 (treatment works)	6397320 330443
	6 (receiving water)	6397397 330442
3. Brännkläppen landfill site, Boden	7 (leachate)	7319852 807609
	8 (sedimentation pond)	7319423 807317
	9 (Mjösjön)	7318825 807890
4. Skanska, Luleå	10 (wash pond)	7287980 826751
5. Trollbo, Säter	11 (Trollbo 1)	6699371 545870
	12 (Trollbo 2)	6699265 546111

Site 1: Recycled concrete in road, Tanumshede

During motorway construction north of Tanumshede, a bridge was demolished. The concrete from the bridge was crushed to be used in a road bank for a new bridge over the E6 motorway. The original concrete bridge base was formed in 1995 and the concrete was torn down in early summer 2010 and placed directly in the new road construction. The concrete now lies beneath the surface asphalt and above the groundwater level. Two samples were taken from potentially contaminated points and at a reference point. Potentially contaminated samples were taken a t two distances from the recycled concrete (Figure 1). One point was selected to be as close to the concrete as possible (Point 2), with a maximum chance of reaching high levels. The other point was placed downstream from the wetland that received water from the road (Point 3). The reference sample was taken further north, close to the road where recycled concrete had not been used (Point 1).

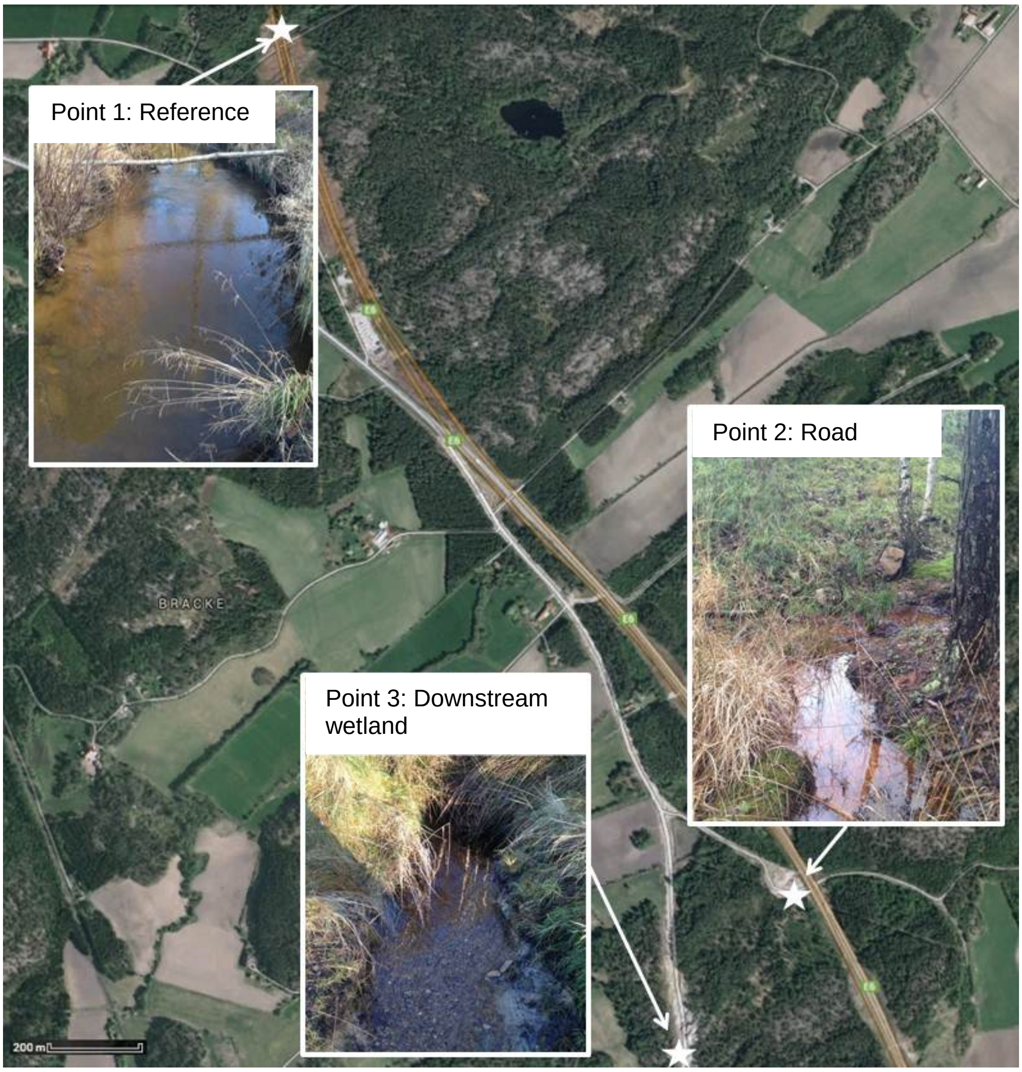

Figure 1. *Samples were taken at three points, to investigate leaching and spread of concrete additives from the road construction. Point 1 is a reference point upstream that has not been affected by the recycled concrete. Point 2 was selected to be as close to the recycled concrete as possible. Point 3 was located approx. 300m from the concrete road construction.*

Double samples were taken on two occasions at the three points to reveal any variation. The sampling occasions were chosen to represent leaching conditions during different seasons. Sampling was carried out on 8/11/2012 and 25/6/2013.

Site 2: Fläskebo landfill outside Göteborg

The Fläskebo landfill east of Göteborg has received considerable amounts of concrete. To maximize the likelihood of detecting concrete additives, sampling was carried out in leachate from the area of the landfill where most concrete has been disposed (Point 4). The proportion of concrete in this part of the landfill is estimated at approximately 5%. Samples were also taken after treatment, but prior to the peat filter (Point 5) and in outflowing water to the receiving water (Point 6).

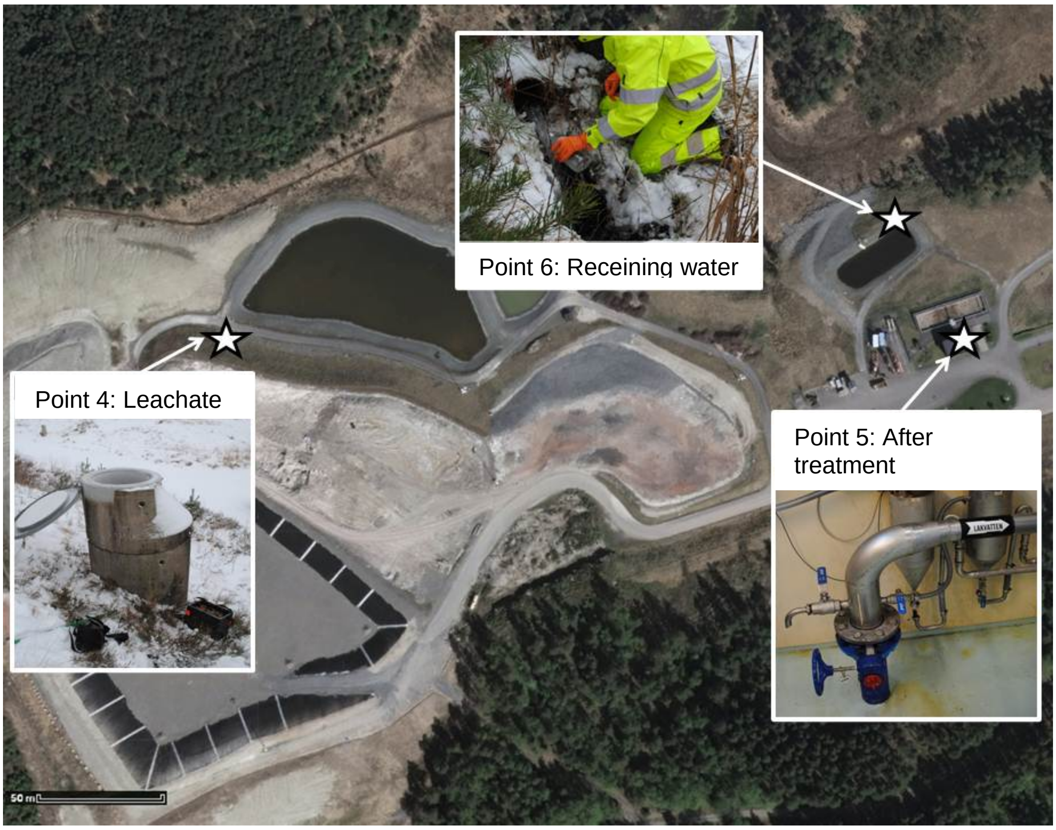

Figure 2. *Samples were taken at three points, to investigate leaching and spread of concrete additives from the road construction. Point 4 is leachate from the landfill area with most concrete. Point 5 is water that has been treated. Point 6 is water that has been released into receiving water after treatment and peat filtration.*

Double samples on two occasions were also taken at this site to reveal any variation. The sampling occasions were chosen to represent leaching conditions during different seasons. Sampling was carried out on 15/1/2012 and 20/5/2013.

Site 3: Brännkläppen landfill

Brännkläppen landfill in Boden was sampled on 03/6/2013. This sampling was initiated by Norrbotten County Administrative Board. To obtain more sampling points and double samples, it was partially financed by the concrete additive screening programme. Three samples were taken on and beside the landfill. The sampling points were located in a leachate ditch at the landfill site (Point 7), in a sedimentation pond (Point 8) and in the receiving water (Point 9) The receiving water was a lake (Mjösjön) where the leachate ends up after passing through a wetland.

Figure 3. *Three samples were taken at Brännkläppen landfill, of which two were within the landfill site and one in Mjösjön, the receiving water for leachate from the landfill.*

Site 4: Skanska, Luleå

Norrbotten County Administrative Board carried out sampling at Skanska's plant in Luleå. The plant produces concrete which is distributed mainly in the Luleå area by lorry. The lorries are cleaned daily at the end of each shift. Sampling was carried out in a wash pond (Point 10) where the water from concrete lorries is collected after the lorries' tanks have been cleaned. At sampling the cleaning had not been started that day, meaning that the water from the day before was left in the pond. Skanska supplied material safety data sheets for Portland cement and additives to allow a comparison of sampling results with the substances used in concrete production.

Figure 4. *Sampling point at the wash pond at Skanska's concrete plant, where the water from concrete lorries is collected after the lorries' concrete tanks have been cleaned.*

Site 5: Trollbo

The Dalarna County Administrative Board conducted sampling at an industrial landfill in Säter (Trollbo). The landfill is situated on both sides of Highway 266, and designated as Trollbo 1 (Point 11) and Trollbo 2 (Point 12). Sampling was carried out on 4/12/2012.

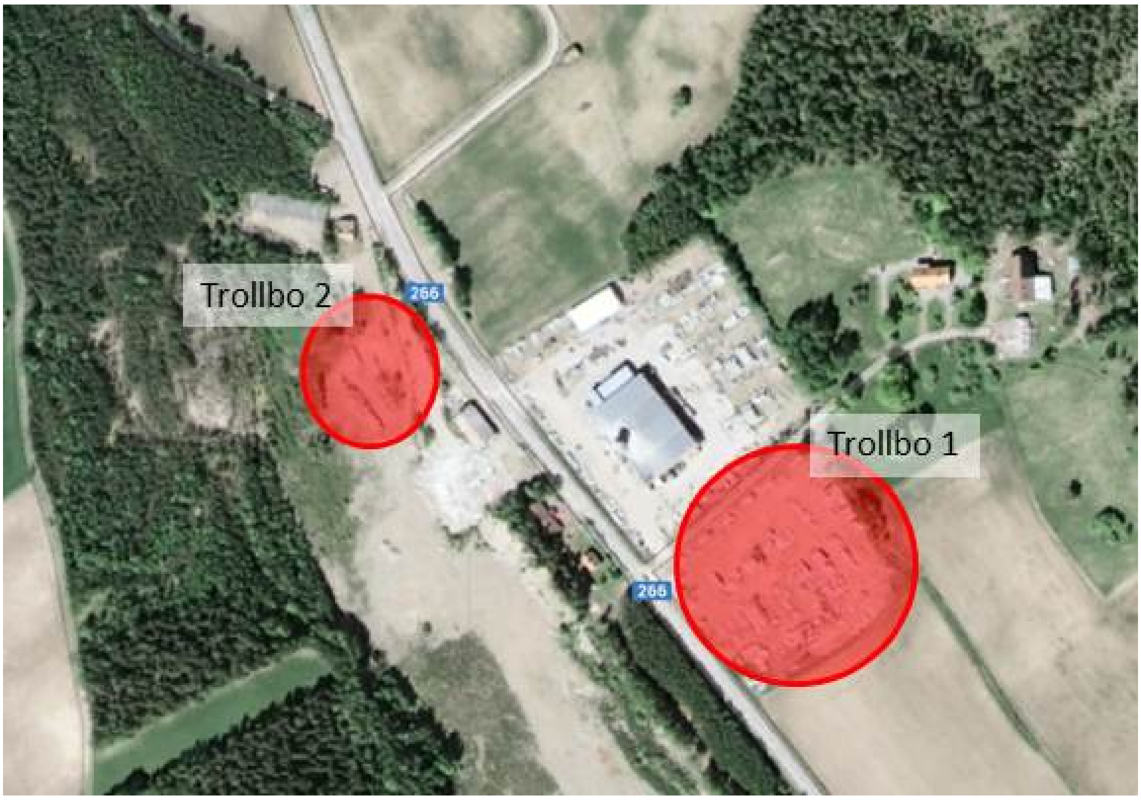

Figure 5. *There are two landfill sites at Trollbo, on either side of Highway 266. These are designated Trollbo 1 and Trollbo 2, as in the figure.*

3 Analyses of PAHs and PCBs

In addition to the concrete additives presented above, PAH and PCB have been analysed (/PAH-16 and PCB-7). The measurements included in the PAH-16 and PCB-17 analyses are shown in Table 3, including detection limits. PAH has been analysed as a reference substance because it is common to find relatively high concentrations of PAH close to roads. PCB has been included because it has been used as a sealant and expansion joint element in bridges, and might therefore pose an environmental threat if it leaches from recycled concrete or disposed concrete in landfill.

PAH was analysed at all sites except Trollbo. PCB was analysed at all sites except Trollbo and Skanska’s concrete plant.

Table 3. *Analysed PAH och PCB, including different totals for PAH, and detection limits.*

Chemical	Detection limit (µg/l)
Benzo(a)anthracene	0,02
Chrysene	0,02
Benzo(b,k)fluoranthene	0,04
Benzo(a)Pyrenee	0,02
Indeno(1,2,3-cd)Pyrenee	0,02
Dibenzo(a,h)anthracene	0,02
Sum carcinogenic PAHs	0,02
Naphthalene	0,02
Acenaphthylene	0,02
Acenaphthene	0,02
Fluorene	0,02
Phenanthrene	0,02
Anthracene	0,02
Fluoranthene	0,02
Pyrene	0,02
Benzo(g,h,i)perylene	0,02

Chemical	Detection limit (μg/l)
Sum other PAHs	0,3
Sum low molecular weight PAH	0,2
Sum medium molecular weight PAH	0,3
Sum high molecular weight PAH	0,3
PCB-28	0,01
PCB-52	0,01
PCB-101	0,01
PCB-118	0,01
PCB-138	0,01
PCB-153	0,01
PCB-180	0,01

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5 Ecotoxicological risk

Based on ecotoxicological tests, a substance’s toxicity can be estimated and given a PNEC value (Predicted No Effect Concentration). The PNEC value is the highest concentration in the environment that is not expected to cause any biological effect, and can therefore serve as a safe limit. In this study PNEC values were obtained for all concrete additives in accordance with the European Commission’s guidance document on ecological risk assessment (European Commission 2003).

The minimum amount of ecotoxicological information that is required to obtain a PNEC value is acute toxicity for three trophic levels: algae, daphnia and fish. For algae the results are usually presented in the form of an IC_{50}-value (Inhibitory Concentration, 50%). This is the concentration in which algal growth is limited to 50%, i.e. half of normal, after 72 hours. For daphnia, EC_{50} (Effective Concentration, 50%) is presented, which is the concentration in which 50% of the daphnia can no longer move after 48 hours. For fish LC_{50} (Lethal Concentration, 50%) is used. This is the concentration in which 50% of the fish die within 96 hours. If information is available for all three trophic groups, then PNEC is assigned by dividing the lowest of the three values by a safety factor of 1000. This is regarded as a conservative assessment that protects the environment from any uncertainties in the data. For some chemicals information was available for just two trophic levels. In these cases the lower of the two values was used to assign PNEC (Table 4).

In some cases information was also available on toxicity in chronic tests. This information is expressed as NOEC (No Observed Effect Concentration), which is the highest investigated concentration at which no effect has been noted. If one or more NOEC values are available, the PNEC value can be raised by using a lower safety factor (European Commission 2003).

Table 4. *Acute and chronic toxicity for algae, daphnia and fish, and resulting PNEC (Predicted No Effect Concentration). PNEC is assigned in accordance with the European Commission (2003).*

Chemical	**Acute toxicity (mg/l)**			**Chronic toxicity (mg/l)**			**PNEC (μg/l)**
	IC_{50} algae	**EC_{50} daphnia**	**LC_{50} fish**	**NOEC algae**	**NOEC daphnia**	**NOEC fish**	
4NP	1,3[1]	0,218[1]	0,13[1]	0,5[1]	0,024[1]	0,006[1]	0,6
4NPEO1	37,4[2]		1[2]				1
4NPEO2	37,4[2]		1[2]				1
4tOP	1,9[1]	0,28[1]	0,26[1]	1[1]	0,03[1]	0,012[1]	1,2
4tOPEO1	5000[2]	26[2]	8,9[2]				8,9
4tOPEO2	5000[2]	26[2]	8,9[2]				8,9
Thiocyanate	150[2]	3,56[2]	83[2]			16,6[3]	3,56
Pimaric acid		0,26[4]	0,8[5]				0,26
Abietic acid		0,68[4]	0,7[5]				0,68
Dehydroabietic acid		1,28[4]	1,1[5]				1,1

[1] European Chemicals Agency (ECHA), Registered Substances. http://echa.europa.eu/

[2] Kemiska ämnen – Prevent. http://www.prevent.se/kemiskaamnen/

[3] Lanno and Dixon. 1994. Chronic toxicity of waterborne thiocyanate to fathead minnow (*Pimephales promelas*) - A partial life-cycle study. Environmental Toxicology and Chemistry 13(9):1423-1432

[4] Peng and Roberts. 2000. Solubility and toxicity of resin acids. Water Research 34(10):2779-2785

[5] Leach and Thakore. 1976. Toxic constituents in mechanical pulping effluents. Tappi 59(2):129–132

6 Results, Screening of concrete additives

All samples were analysed by Eurofins. The results are presented below, by site, with an assessment of the ecotoxicological risk. Note that for thiocyanate and resin acids the detection limits lie over the PNEC values in Table 4. Thus, although the concentration is below the detection limit, this does not guarantee that the risk for the ecosystem is acceptable.

Site 1: Recycled concrete in road, Tanumshede

Tables 5 and 6 show the analysis results from November and June for the recycled concrete that was used in the construction of a road in Tanumshede. For thiocyanates and nonyl and octylphenol compounds, no levels were detected over the detection limit. However, levels were high for several resin acids. For abietic acid all measurements fell above the detection limit, while for dehydroabietic acid three measurements were above the detection limit, and for pimaric acid one measurement was above the detection limit. Since levels of abietic acid and dehydroabietic acid were equally high at the reference point and at the road, the recycled concrete in the road can be discounted as the source of these resin acids. One measurement of pimaric acid was above the detection limit. This was at site 3, downstream from the wetland. It is also unlikely in this case that the recycled concrete was the source, since the level was lower (below the detection limit) at the actual site of the recycled concrete. Note that all measurements that were above the detection limit were also far above the PNEC values. For example, levels of abietic acid were 450 times higher than the PNEC value at all sampling points. This means that effects of organisms are likely. The cause of these high levels is uncertain and need to be investigated further. Natural sources cannot be ruled out, since pine trees are abundant in the area, and these are a known source of certain resin acids. Levels are high compared with levels at Lake Bolmen in western Småland. Total levels of resin acids in this lake were recorded In 2009 as up to 18 µg/l (Eurofins och Pelagia 2010). The levels are in the same magnitude as those in runoff from log yards in Canada (Alberta Environment, 2002).

The large differences between the two samples at point 3 (downstream from the wetland) are difficult to explain.

Table 5. *Analysed chemicals at the road constructed with recycled concrete. Sampling carried out 8/11/2012. All concentrations in µg/l.*

Chemical	1. Reference		2. At road		3. Downstream wetland	
	A	B	A	B	A	B
4NP	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1
4NPEO1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1
4NPEO2	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1
4tOP	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01
4tOPEO1	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01
4tOPEO2	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01
Thiocyanate	<5,00	<5,00	<5,00	<5,00	<5,00	<5,00
Pimaric acid	<1	<1	<1	<1	<1	16
Abietic acid	297	306	289	282	308	302
Dehydroabietic acid	<1	22	18	<1	<1	603

The results differed at the second sampling occasion at Tanumshede. This time 4tOP clearly exceeded the detection limit in the two samples from the roadside. However, the values were well below the PNEC (1.2 µg/l), so the ecological risk is very small Resin acids were now under the detection limit in many cases. At two sampling sites, pimaric acid and abietic acid exceeded the detection limits and also the PNEC values.

Table 6. *Analysed chemicals at the road constructed with recycled concrete. Sampling carried out 25/6/2013. All concentrations in µg/l.*

Chemical	1. Reference		2. At road		3. Downstream wetland	
	A	B	A	B	A	B
4NP	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1
4NPEO1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1
4NPEO2	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1
4tOP	<0,01	<0,01	0,05	0,04	<0,01	<0,01
4tOPEO1	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01

Chemical	1. Reference		2. At road		3. Downstream wetland	
	A	B	A	B	A	B
4tOPEO2	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01
Thiocyanate	<5,00	<5,00	<5,00	<5,00	<5,00	<5,00
Pimaric acid	<1	<1	7	4	<1	<1
Abietic acid	<1	<1	<1	3	<1	3
Dehydroabietic acid	<1	<1	<1	<1	<1	<1

Site 2: Fläskebo landfill outside Göteborg

Tables 7 and 8 show the analysis results from January and May at the Fläskebo landfill site outside Göteborg. Two phials from the resin acid sampling in May were damaged during transport to the lab. These comprised of one sample from the area of the landfill with most concrete and one from the point after treatment. This means that results are available from all points, even though in two cases there were only single samples.

Concentrations were generally higher at the sampling in May, with 24 measurements above the detection limit. For the sampling in January there were only four measurements where the detection limit was exceeded. Unlike the measurements at Site 1, there were many nonyl and octyl phenol compounds that exceeded the detection limit. However, these were in all cases below the PNEC values.

The concentration of resin acids was considerably lower than at Site 1, but still exceeded the PNEC values.

Table 7. *Analysed chemicals at Fläskebo landfill. Sampling carried out 15/1/2015. All concentrations in µg/l.*

Kemikalie	4. Lakvatten		5. Efter rening		6. Till receiving water	
	A	B	A	B	A	B
4NP	0,2	0,2	<0,1	<0,1	<0,1	<0,1
4NPEO1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1

Kemikalie	4. Lakvatten		5. Efter rening		6. Till receiving water	
	A	B	A	B	A	B
4NPEO2	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1
4tOP	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01
4tOPEO1	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01
4tOPEO2	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01
Thiocyanate	<5,00	<5,00	<5,00	<5,00	<5,00	<5,00
Pimaric acid	<1	<1	<1	<1	<1	<1
Abietic acid	<1	6	<1	11	<1	<1
Dehydroabietic acid	<1	<1	<1	<1	<1	<1

Table 8. *Analysed chemicals at Fläskebo landfill. Sampling carried out 20/05/2013. All concentrations are in $\mu g/l$. Two sampling phials (4B and 5B) of resin acids were damaged during transport and were not analysed.*

Chemical	4. Leachate		5. After treatment		6. To receiving water	
	A	B	A	B	A	B
4NP	0,28	0,27	0,11	<0,1	0,17	0,13
4NPEO1	<0,1	0,16	<0,1	<0,1	<0,1	<0,1
4NPEO2	<0,1	<0,1	0,14	<0,1	<0,1	<0,1
4tOP	0,06	0,07	0,02	<0,01	0,02	0,01
4tOPEO1	0,01	0,01	0,01	<0,01	<0,01	<0,01
4tOPEO2	0,02	0,08	0,01	<0,01	0,02	0,01
Thiocyanate	<5,00	<5,00	<5,00	<5,00	<5,00	<5,00
Pimaric acid	<1	n/a	<1	n/a	<1	8
Abietinsyra	<1	n/a	<1	n/a	<1	<1
Dehydriabietinsyra	<1	n/a	3	n/a	2	4

Site 3: Brännkläppen landfill site

Table 9 shows all analyses from Brännkläppen landfill site. The detection limit for 4-tert-Octylphenol (4tOP) was exceeded in all samples, with concentrations of 0.03-0.05 µg/l. This is well below the PNEC value (1.2 µg/l).

Concentrations of resin acids also exceeded the detection limit in several samples. It was largely dehydroabietic acid that exceeded the detection limit. Levels were of approximately the same as those at Fläskebo landfill (Site 2), i.e. far lower than at Site 1 (the road), but still higher than the PNEC values.

Thiocyanate also exceeded the detection limit at one sampling point, and were therefore higher than the PNEC value. The high thiocyanate levels were measured in the sedimentation pond that receives leachate from the landfill.

Table 9. *Analysed chemicals at Brännkläppen landfill site. Sampling carried out 03/6/2013. All concentrations are in µg/l.*

Chemical	7. Dike		8. Sedimentation pond		9. Mjösjön	
	A	B	A	B	A	B
4NP	0,11	<0,100	<0,100	<0,100	<0,100	<0,100
4NPEO1	<0,100	<0,100	<0,100	<0,100	<0,100	<0,100
4NPEO2	<0,100	<0,100	<0,100	<0,100	<0,100	<0,100
4tOP	0,04	0,04	0,04	0,05	0,03	0,04
4tOPEO1	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01
4tOPEO2	<0,01	0,01	<0,01	<0,01	<0,01	<0,01
Thiocyanate	<5,00	<5,00	5,9	6	<5,00	<5,00
Pimaric acid	<1	<1	<1	3	<1	<1
Abietinsyra	<1	<1	<1	<1	<1	<1
Dehydroabietic acid	4	3	5	5	4	<1

Site 4: Skanska, Luleå

Table 10 shows the analysis results from Skanska in Luleå. The detection limit was exceeded for 4-tert-Octylphenol (4tOP) and all resin acids. The 4tOP level was still well below the PNEC value (1.2 µg/l) but resin acids were 35-100 times higher than the PNEC values.

Table 10. *Analysed chemicals at Skanska in Luleå. Sampling carried out 22/5/2013. All concentrations are in µg/l. Sampling was only carried out at one point.*

Chemical	10. Skanska
4NP	<0,100
4NPEO1	<0,100
4NPEO2	<0,100
4tOP	0,09
4tOPEO1	<0,01
4tOPEO2	<0,01
Thiocyanate	<5,00
Pimaric acid	29
Abietic acid	24
Dehydroabietic acid	69

Site 5: Trollbo

Table 11 shows all the results from measurements of concrete additives at Trollbo. At Trollbo 1 only levels of dehydroabietic acid exceeded the detection limit. These levels were also (15 times) higher than the PNEC value.At Trollbo 2 the detection limit was exceeded for abietic acid and dehydroabietic acid. Both levels were higher (approx. 20 times) than the PNEC values.

Table 11. *Analysed chemicals at the landfills Trollbo 1 and Trollbo 2. Sampling carried out 04/12/2012. All concentrations in µg/l.*

Chemical	11. Trollbo 1	12. Trollbo 2
4NP	<1,0	<1,0
4NPEO1	<1,0	<1,0
4NPEO2	<1,0	<1,0
4tOP	<0,1	<0,1

Chemical	11. Trollbo 1	12. Trollbo 2
4tOPEO1	n.a.	n.a.
4tOPEO2	n.a.	n.a.
Thiocyanate	<5,00	<5,00
Pimaric acid	<1	<1
Abietinsyra	<1	13
Dehydroabietic acid	16	25

7 Results, PAHs and PCBs

At the first sampling occasion (08/11/2012) at the road in Tanumshede (Site 1), PAH levels were below the detection limit. This is surprising for a sampling point so close to a busy road. A possible explanation for the low levels is that it had not rained for a long time, and that PAH had not been flushed into the water at the side of the road. When the same point was sampled a second time (25/6/2013), detection limits were greatly exceeded for most PAH compounds in both samples nearest the road (Table 12). 4tOP and pimaric acid followed the same pattern at this sampling point, which indicates that they are spread from the road in a similar way.

At the landfills and Skanska, naphthalene was the only PAH that exceeded the detection limit. This was the case at all sampling points at Fläskebo landfill outside Göteborg on 20/5/2013. However, the levels only slightly exceeded the detection limit (0.024-0.038 µg/l). At Brännkläppen landfill in Boden, levels of naphthalene slightly exceeded the detection limit in one of the samples in the ditch (0.022 µg/l). Levels of naphthalene were also slightly over the detection limit at Skanska in Luleå (0.024 µg/l).

No samples contained PCB levels that exceeded the detection limit.

Table 12. *PAH levels at Tanumshede, Point 2 (close to road).*

Chemical	**Tanumshede Point 2, At the road 25/6/2013**	
Benzo(a)Anthracene	0,062	0,048
Chrysene	0,052	0,036
Benzo(b,k)fluoranthene	0,066	0,070
Benzo(a)Pyrenee	0,032	0,044
Indeno(1,2,3-cd)Pyrenee	0,034	0,042
DiBenzo(a,h)Anthracene	< 0,02	< 0,02
Summa cancerogena PAH	0,26	0,25
Naphthalene	0,17	3,2
Acenaphthylene	0,15	0,07
Acenaphthene	0,77	0,52
Fluorene	1,3	1,3

Chemical	Tanumshede Point 2, At the road 25/6/2013	
Phenanthrene	0,028	0,82
Anthracene	0,16	0,17
Fluoranthene	0,72	0,37
Pyrene	0,32	0,20
Benzo(g,h,i)perylene	0,020	0,024
Summa övriga PAH	3,7	6,7
ΣPAH med låg molekylvikt	1,1	3,8
ΣPAH med medelhög molekylvikt	2,6	2,8
ΣPAH med hög molekylvikt	< 0,30	< 0,30

Table 13. *Naphthalene levels in different sites at two different sampling occasions*

Site	Point	Halt (µg/l)		Halt (µg/l)	
1. Road, Tanumshede	1 (reference)	<0,02	<0,02	< 0,02	< 0,02
	2 (road)	<0,02	<0,02	0,17	3,2
	3 (downstream wetland)	<0,02	<0,02	< 0,02	< 0,02
2. Fläskebo landfill, Landvetter	4 (leachate)	<0,02	<0,02	0,028	<0,02
	5 (treatment works)	<0,02	<0,02	0,028	0,038
	6 (receiving water)	<0,02	<0,02	0,024	0,036
3. Brännkläppen landfill site, Boden	7 (leachate)	0,022	<0,02	n/a	n/a
	8 (sedimentation pond)	<0,02	<0,02	n/a	n/a
	9 (Mjösjön)	<0,02	<0,02	n/a	n/a
4. Skanska, Luleå	10 (wash pond)	0,024	n/a	n/a	n/a

8 Conclusions

Nonyl and octylphenol compounds levels were generally below the detection limit, and when they could be measured they were well below the PNEC values, which are regarded as the limit for acceptable ecological risk. The results of this study clearly show that leaching of these substances from recycled or disposed concrete does not pose an ecological risk.

Thiocyanate exceeded the detection limit at one sampling point (sedimentation pond at Brännkläppen landfill). Levels here (5.9 and 6.0 µg/l) were only just over the detection limit, but still exceeded the PNEC value (3.56 µg/l). Since detection limits were somewhat higher than the PNEC value, it cannot be ruled out that this was not exceeded at several sites. Renewed screening of thiocyanate with a lower detection limit is needed to carry out a more reliable assessment of the ecotoxicological risk.

The results for resin acids are more difficult to interpret. The highest levels were measured in samples taken at Tanumshede on 08/11/2012. Levels of abietic acid and dehydroabietic acid greatly exceeded the PNEC values. However, there was no apparent gradient with higher levels nearer the road with the recycled concrete. It is therefore reasonable to assume that the source of these substances is something other than the recycled concrete in the road. A possible explanation is that resin acids are released from the surrounding pine forest. Pine is a known source of resin acids. At the second sampling occasion (25/6/2013), levels of both abietic acid and dehydroabietic acid were under the detection limit in all samples. A possible explanation for this is seasonal variation in the biology of pine, as well as fluctuations in the water flow. At the second sampling occasion, it was pimaric acid and abietic acid that exceeded the detection limits. Pimaric acid was present in both samples from the sampling point nearest the road one sample taken close to the road and one sample taken downstream.. In this case it is likely that the road is the source. However, levels were well below the PNEC value. At this sampling point, PAH levels were also significantly lower than during autumn, indicating that conditions for chemical leaching from the road had changed.

The risk for leaching of PCB from recycled concrete is considered low, why no precautionary measures are suggested.

The results of this study suggest that the ecotoxicological risk of leaching from recycled concrete is low for nonyl and octylphenol compounds and for resin acids.

For thiocyanate it was not possible to rule out any ecological risk, since the detection limit was too high. However, it is unlikely that thiocyanate would pose an ecological risk after dilution in the receiving water, since the highest levels were only somewhat above the PNEC value. No precautionary measures are suggested to reduce emissions from recycled concrete or concrete landfills.

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